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(54) **ELECTRICAL SKIN REJUVENATION**

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See application file for complete search history.

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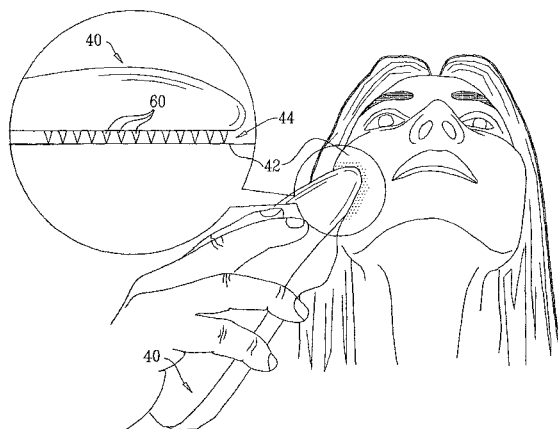
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(57)

ABSTRACT

A method is provided for reducing a wrinkle on a skin surface (42). The method includes identifying a person having a skin surface (42) with a wrinkle and in response to identifying the person, positioning at respective sites on the skin surface (42) an array (44) of electrodes (60) coupled to an energy source (46). While the electrodes (60) are at the respective sites: during a first time period, applying energy from the energy source (46) to drive the electrodes (60) to apply radio frequency (RF) current at a first voltage, capable of ablating an epidermal layer of the skin; and during a second time period, applying energy from the energy source (46) to drive the electrodes (60) to apply current at a second voltage, lower than the first voltage. Other embodiments are also described.

10 Claims, 2 Drawing Sheets



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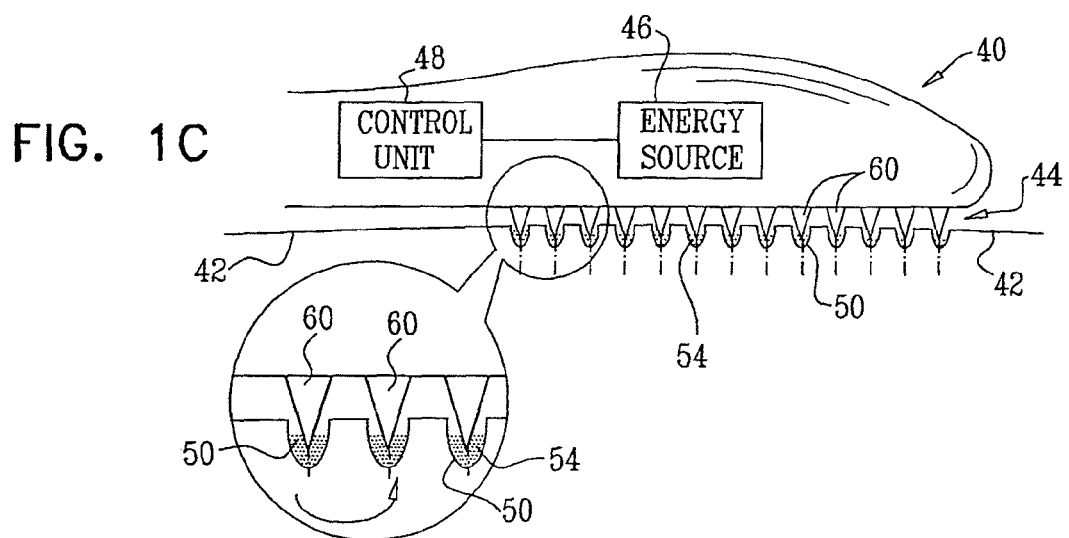
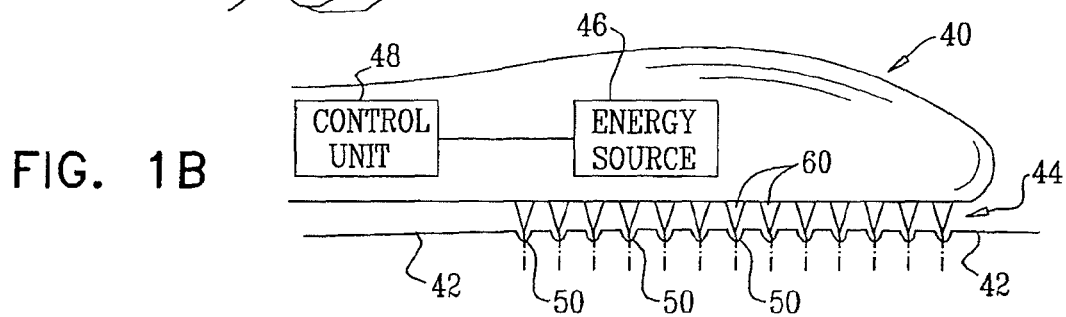
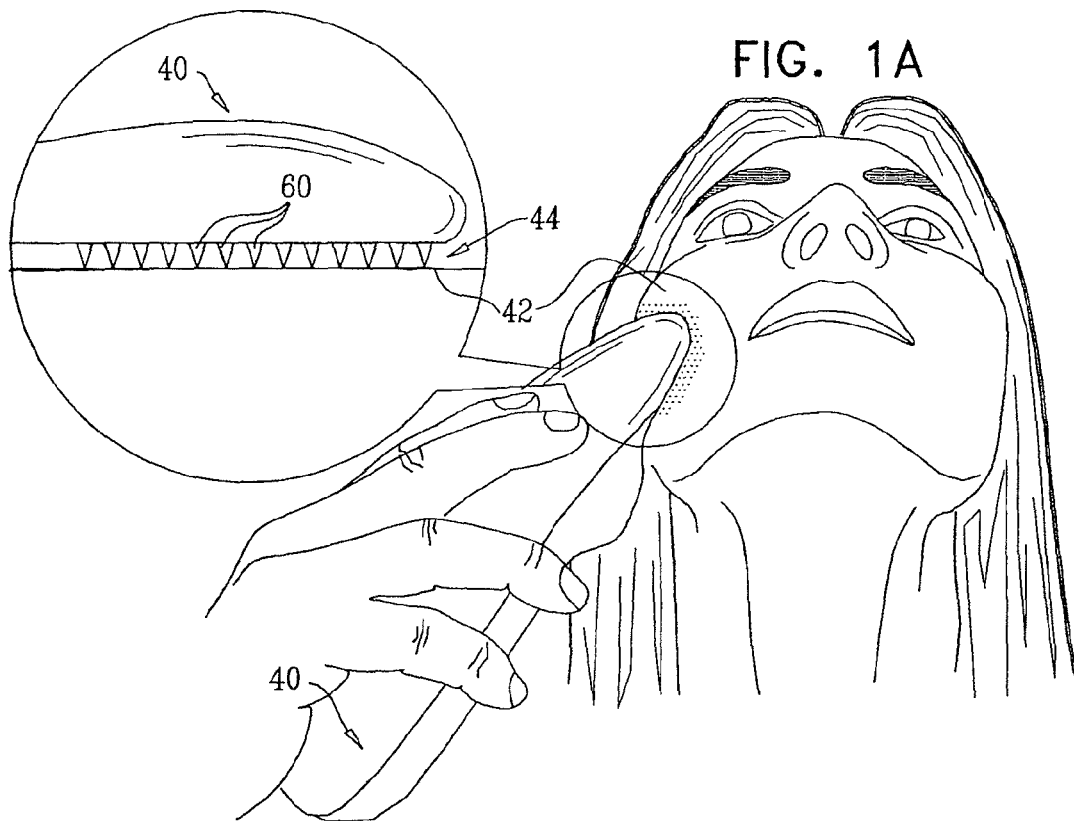
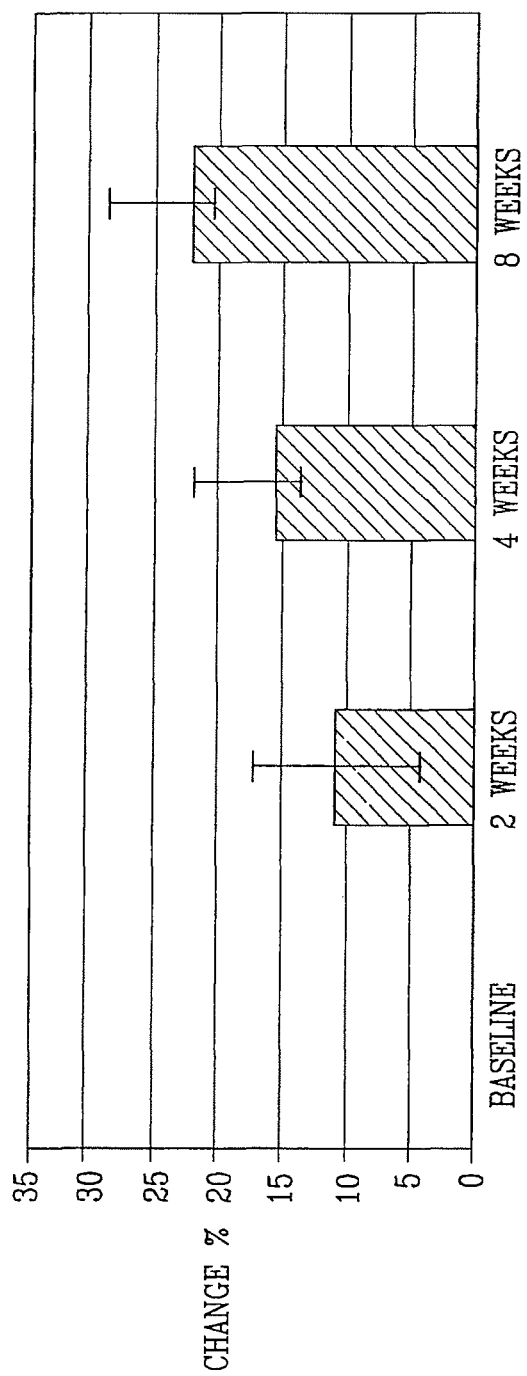


FIG. 2



ELECTRICAL SKIN REJUVENATION**CROSS-REFERENCES TO RELATED APPLICATIONS**

The present application claims the priority of U.S. Provisional Application 61/208,621 to Levin, entitled, "Electrical skin rejuvenation," filed Feb. 25, 2009, which is incorporated herein by reference.

FIELD OF EMBODIMENTS OF THE INVENTION

Some embodiments of the present invention relate generally to skin rejuvenation, and particularly to methods and apparatus for wrinkle reduction.

BACKGROUND

Skin, the body's largest organ, is composed of multiple layers. The outer layer, epidermis, is divided into several sublayers; the outermost layer is termed stratum corneum epidermidis. The stratum corneum is generally a non-innervated cell layer consisting of mainly large, dead cells that lack nuclei. Beneath the epidermis, lies the dermis skin layer, which is tightly connected to the epidermis.

A major structural component of the skin is collagen, a fibrous protein, which contributes to skin strength and elasticity. As such, collagen formation and remodeling lead to changes in mechanical properties of the skin such as texture and resilience. Typically, collagen plays an important role in the regeneration of epidermal tissue in wounded skin. Collagen is produced during the wound healing process, thus increasing the tensile strength of a wound.

Collagen contraction, or thermal shrinkage of collagen, occurs by the dissociation of heat-sensitive bonds of the collagen molecule. Thermal denaturing of collagen results in a tightening effect of the skin. In contrast, age-related degradation of collagen leads to sagging of the skin and the formation of wrinkles. Many wrinkles appear on exposed areas of the skin, e.g., the face, the neck and the forearms. These visible effects of aging of the skin are disturbing to some individuals, and therefore methods for rejuvenation of maturing or damaged skin are of interest.

U.S. Pat. No. 6,461,354 to Olsen et al. describes systems and methods for selectively applying electrical energy to a target location on an external body surface, such as for skin tissue removal and/or collagen shrinkage in the epidermis or dermis, e.g., the removal of pigmentations, vascular lesions (e.g., leg veins), scars, tattoos, etc., and for other surgical procedures on the skin, such as tissue rejuvenation, cosmetic surgery, wrinkle removal, hair removal and/or transplant procedures. The described system and methods apply high frequency (RF) electrical energy to one or more electrode terminals adjacent an external body surface, such as the outer surface of the skin, to remove and/or modify the structure of tissue structures within the skin. Depending on the specific cosmetic procedure, the described system and methods may be used to: (1) volumetrically remove tissue or hair (i.e., ablate or effect molecular dissociation of the tissue structure); (2) separate a tissue layer from an underlying tissue layer so that the tissue layer can be removed; (3) shrink or contract collagen connective tissue; and/or (4) coagulate blood vessels underlying the surface of the skin.

U.S. Pat. No. 6,381,498 to Knowlton describes a method and apparatus that applies radiant energy through the skin to underlying collagen tissue, and is described as not substan-

tially modifying melanocytes and other epithelial cells in the epidermis. A membrane is adapted to receive an electrolytic solution and become inflated to substantially conform to a contacting exterior surface of the membrane to a skin layer. The membrane includes a cooling lumen for receiving cooling fluid. One or more thermal electrodes positioned in the membrane transfers thermal energy to the electrolytic solution. The electrolytic solution and cooling fluid is described as creating a reverse thermal gradient from the skin surface to the underlying collagen tissue. A thermal power source is coupled to the thermal electrodes, and a source of electrolytic solution is coupled to the membrane.

US 2006/0036300 to Kreindel describes a method of lipolysis. The method comprises deforming a region of skin so that the region of skin protrudes from surrounding skin. One or more radio frequency (RF) electrodes are positioned on the protruding region of skin so as to generate an electrical current through adipose tissue in the protruding region of skin when a voltage is applied to the electrode or electrodes. A voltage is then applied to the electrode or electrodes so as to deliver sufficient RF energy to the protruding region of skin to damage subcutaneous adipose tissue. The described method may be used, for example, to achieve a reduction in body weight, cellulite reduction, loose skin reduction, wrinkle treatment, body surface tightening, skin tightening, and collagen remodeling.

U.S. Pat. No. 6,684,107 to Binder describes a system for reducing wrinkles on human skin that utilizes an electrode to conduct a microcurrent through the surface of the wrinkle into the underlying dermal layer. The electrode is moved in multiple passes along the length of the wrinkle, with the electrode in contact with the surface of the wrinkle while generating a periodically repeating microcurrent having a peak amplitude in the range of 10-40 microamps, a peak current density in the range of 10-50 microamps/cm.², and a frequency in the range of 5-15 Hz. The electrode device is described as self-contained in a battery-containing, cordless case from which a contact electrode protrudes. A hand-engaging second electrode on the surface of the case completes a conductive path through the user's body.

U.S. Pat. No. 6,148,232 to Avrahami describes a device for ablating the stratum corneum epidermidis of a subject, including a plurality of electrodes, which are applied to the subject's skin at respective points. A power source applies electrical energy between two or more of the plurality of electrodes, in order to cause ablation of the stratum corneum primarily in an area intermediate the respective points.

U.S. Pat. No. 6,611,706 to Avrahami describes a device for facilitating transdermal passage of a substance through skin on the body of a subject. The device preferably includes an electrode and a control unit. In a preferred embodiment, the control unit is adapted to drive the electrode to apply to the skin a current capable of ablating stratum corneum epidermidis of the skin, so as to facilitate transdermal passage of the substance. The control unit detects generation of at least one spark responsive to application of the current, and modifies a parameter of the current responsive to detecting the generation of the at least one spark.

U.S. Pat. No. 6,708,060 to Avrahami describes a device for treating skin on the body of a subject. The device includes a plurality of electrodes, which are adapted to be placed in contact with the skin and then moved across the skin while maintaining electrical contact with the skin. The device additionally includes a power source, which is adapted to apply a current between two or more of the plurality of electrodes at the same time as the electrodes are being moved across the skin.

Reliant Technologies (California, US) distributes the Fraxel family of cosmetic products, which includes three fractional lasers that produce two non-ablative treatments and one ablative treatment.

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U.S. Pat. No. 6,179,836

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U.S. Pat. No. 6,381,498

U.S. Pat. No. 6,387,380

U.S. Pat. No. 6,405,090

U.S. Pat. No. 6,413,255

U.S. Pat. No. 6,432,103

U.S. Pat. No. 6,461,354

U.S. Pat. No. 6,468,270

U.S. Pat. No. 6,482,201

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U.S. Pat. No. 6,632,193

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U.S. Pat. No. 6,832,996

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WO 03065915

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WO 06054150

WO 06080012

WO 06109334

SUMMARY

In some applications of the present invention, an apparatus and a method for reducing a wrinkle on a skin surface is provided. An array of electrodes coupled to an energy source is positioned on the wrinkle. The electrodes remain at the same sites on the skin surface for at least two successive periods of time. During the first period of time, energy from the energy source is applied to drive the electrodes to apply radio frequency (RF) current at a first voltage. The current applied at the first voltage is capable of locally ablating the epidermal tissue (and typically superficial dermal tissue) in close proximity to the electrodes. Ablation of the epidermal tissue (and typically superficial dermal tissue) by the applied RF current generates micro-channels through the epidermis (and typically superficial dermis). The formation of the micro-channels induces natural body fluid to enter the micro-channels. Whereas during ablation the resistance between electrodes increases, the resistance subsequently decreases when body fluid enters the micro-channels. During the subsequent, second time period, energy from the energy source is applied to drive the electrodes to apply current at a second voltage, lower than the first voltage. The current applied at the second voltage is sufficient to continuously heat the fluid within the micro-channels and underlying tissue, but generally does not cause further ablation.

The inventors hypothesize that the ablation of epidermal tissue (and typically superficial dermal tissue) with subsequent heating of underlying tissue leads to collagen regeneration and remodeling, resulting in skin rejuvenation. The first phase of RF application ablates micro-channels in the epidermal layer (and typically superficial dermal layer) of the skin in close proximity to the electrodes, as described hereinabove. The ablation of the micro-channels triggers the initiation of a wound healing process in the skin, in which production of collagen is induced. The second phase of lower voltage, non-ablating current application heats the natural body fluid present within the micro-channels, leading to the controlled heating of underlying collagen tissue, causing thermally-mediated collagen contraction. The effect of the combined ablation and heating method of these applications of the present invention is skin tightening and wrinkle reduction. It is noted that although a wound healing process is initiated, ablation of micro-channels into the epidermis (and typically superficial dermis), as provided herein, generally does not cause pain to a subject.

The term "micro-channel," as used in the context of the present patent application and in the claims, refers to a pathway generally extending from the surface of the skin through at least the epidermis. Such micro-channels are formed due to local power dissipation leading to ablation of the epidermis (and typically superficial dermis) when an electric field of sufficient magnitude is applied to a small area of the skin, in contact with the electrodes, for a sufficient period of time.

There is therefore provided, in accordance with some applications of the invention, a method for reducing a wrinkle on a skin surface, including:

- identifying a person having a skin surface with a wrinkle;
- in response to identifying the person, positioning at respective sites on the skin surface an array of electrodes coupled to an energy source; and

- while the electrodes are at the respective sites:

- during a first time period, applying energy from the energy source to drive the electrodes to apply radio frequency (RF) current at a first voltage, capable of ablating an epidermal layer of the skin; and

- during a second time period, applying energy from the energy source to drive the electrodes to apply current at a second voltage, lower than the first voltage.

In some applications, applying energy during the first time period includes applying the energy for 1-20 ms.

In some applications, applying energy during the second time period includes applying the energy for at least 1 second.

In some applications, applying energy during the second time period includes initiating applying the energy through a given electrode during the second time period at least 10 ms after application of energy through the given electrode during the first time period.

In some applications, applying energy during the second time period includes applying only non-ablating energy during the second time period.

In some applications, applying energy during the first time period includes setting a voltage of the energy applied during the first time period to be 150-350 V base-to-peak.

In some applications, applying energy during the second time period includes setting a voltage of the energy applied during the second time period to be 10-200 V base-to-peak.

In some applications, applying energy during the second time period includes setting a voltage of the energy applied during the second time period to be 10-100 V base-to-peak.

In some applications, applying energy during the first time period includes setting a frequency of the energy applied during the first time period to be 50-500 kHz.

In some applications, applying energy during the second time period includes setting a frequency of the energy applied during the second time period to be 50-500 kHz.

In some applications, applying energy during the first time period includes ablating micro-channels in the epidermal layer.

In some applications, applying energy during the second time period includes initiating application of the energy during the second time period subsequently to filling of the micro-channels with body fluid.

There is further provided, in accordance with some applications of the present invention, apparatus for reducing a wrinkle on a skin surface, including:

- an array of electrodes configured to be placed on the skin surface; and

- an energy source coupled to the array of electrodes and configured to apply energy to drive the electrodes to apply ablating current at a first voltage during a first period of time and to apply non-ablating current at a second voltage, lower than the first voltage, during a second period of time.

In some applications, the energy source is configured to apply energy for 1-20 ms during the first time period.

In some applications, the energy source is configured to apply energy for at least 1 second during the second time period.

In some applications, the energy source is configured to apply energy, during the second time period, through a given electrode at least 10 ms after application of energy through the given electrode during the first time period.

In some applications, the energy source is configured to convey to the electrodes 150-350 V base-to-peak during the first period of time.

In some applications, the energy source is configured to convey to the electrodes 10-200 V base-to-peak during the second period of time.

In some applications, the energy source is configured to convey to the electrodes 10-100 V base-to-peak during the second period of time.

In some applications, the energy source is configured to apply energy at a frequency of 50-500 kHz during the first time period.

In some applications, the energy source is configured to apply energy at a frequency of 50-500 kHz during the second time period.

In some applications, the array of electrodes includes at least 10 electrodes.

In some applications, the array of electrodes includes at least 50 electrodes.

In some applications, the electrodes of the array are arranged in a 2xn rectangular array.

In some applications, the array of electrodes includes electrodes, each electrode 60-80 um in diameter.

In some applications, the array of electrodes includes electrodes, each electrode 50-400 um in length.

In some applications, the array of electrodes includes electrodes, each electrode 100-250 um in length.

In some applications, the array of electrodes includes electrodes generally evenly spaced in the array, the distance between adjacent electrodes being 0.5-1.5 mm.

In some applications, the energy source is configured to apply energy capable of ablating micro-channels in an epidermal layer of the skin during the first period of time.

In some applications, the energy source is configured to initiate application of energy subsequently to filling of the micro-channels with body fluid, during the second period of time.

There is yet further provided, in accordance with some applications of the present invention, apparatus for reducing a wrinkle on a skin surface, including:

an array of at least 10 electrodes, each electrode at least 150 μm in length, configured to be placed on the skin surface; and an energy source coupled to the array of electrodes and configured to apply energy to drive the electrodes to apply 50-500 kHz current capable of ablating an epidermis layer of the skin.

In some applications, the array includes at least 100 electrodes.

In some applications, the electrodes of the array are arranged in a $2 \times n$ rectangular array.

In some applications, the electrodes of the array are arranged in an $m \times n$ rectangular array, n being at least four times greater than m .

In some applications, each electrode is 60-80 μm in diameter.

In some applications, the array of electrodes includes electrodes generally evenly spaced in the array, the distance between adjacent electrodes being 0.5-1.5 mm.

There is also provided, in accordance with some applications of the present invention, a method for reducing a wrinkle on a skin surface, including:

identifying a person having a skin surface with a wrinkle; in response to identifying the person, positioning at respective sites on the skin surface at least 10 electrodes coupled to an energy source; and

ablating an epidermal layer of the skin by applying energy from the energy source to drive the electrodes to apply 50-500 kHz current.

The present invention will be more fully understood from the following detailed description of embodiments thereof, taken together with the drawings, in which:

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1A is a schematic illustration of apparatus for reducing wrinkles positioned on a skin surface containing a wrinkle, in accordance with some applications of the present invention;

FIG. 1B is a schematic illustration of an array of electrodes positioned in contact with the skin surface, and respective ablated sites on the subject's skin, in accordance with some applications of the present invention;

FIG. 1C is a schematic illustration of the array of electrodes positioned in contact with the skin surface, during a subsequent heating step, in accordance with some applications of the present invention; and

FIG. 2 is a graph representing an average change in wrinkle depth of eight subjects following application of RF energy, in accordance with some applications of the present invention.

DETAILED DESCRIPTION OF THE EMBODIMENTS

FIG. 1A is a schematic illustration of apparatus 40 for reducing wrinkles, during use by a subject, in accordance with some applications of the present invention. Apparatus 40 is positioned on skin surface 42 containing a wrinkle (e.g., on the face, the forehead or the neck). Apparatus 40 typically comprises an energy source 46, a reusable control unit 48, and a typically disposable sterile array 44 of electrodes 60. When positioned on skin surface 42, array 44 of electrodes 60 is in direct contact with the stratum corneum layer of the skin.

Array 44 is typically 0.5-2 cm^2 (e.g., 0.96 cm^2), and typically comprises 10-1000 electrodes, e.g., 50-250 electrodes.

In all experiments described herein, array 44 comprises 144 electrodes. For some applications (e.g., those used in the experiments described herein), array 44 is arranged as an $n \times n$ array, i.e., a square array of electrodes. For other applications, e.g., where it is desired to primarily apply energy in a series of applications along the length of a wrinkle (and to a lesser extent to surrounding tissue), a long, thin, rectangular array is utilized, e.g., an $m \times n$ array, where m is typically 2, 3, 4, 5, or 6, and n is typically between 10 and 30, or between 30 and 100. For example, the array may be a 2×10 array. For these applications, n is typically at least four times greater than m (e.g., at least eight times greater than m).

Each electrode 60 is typically 60 μm -80 μm in diameter and 50 μm -400 μm in length, e.g., 100-250 μm in length, in order to reach the epidermal tissue (and typically superficial dermal tissue). Array 44 is typically snapped on to a housing of apparatus 40 prior to use and ejected after use.

The distance between adjacent electrodes is typically 0.5-1.5 mm, and the electrodes are typically generally evenly spaced in the array. With an array of small diameter electrodes, which are typically generally evenly-spaced electrodes, and with no particular effort by the operator of the apparatus, generally uniform heating of the skin under array 44 is obtained, particularly during the second time period of energy application (described hereinbelow).

Control unit 48 (FIGS. 1B-C) comprises electronic and software components configured to drive energy source 46 to initiate or discontinue energy application to electrodes 60.

Reference is made to FIG. 1B, which is a schematic illustration of array 44 positioned in contact with skin surface 42, in accordance with some applications of the present invention. In some applications of the present invention, array 44 remains at the same sites on skin surface 42 for at least two periods of time. Energy source 46 applies energy to drive array 44 of electrodes 60 to apply RF energy to skin surface 42. Energy source 46 is configured to apply energy to drive the electrodes to apply current at different voltages during the two time periods. During the first time period, represented in FIG. 1B, energy source 46 applies energy to drive array 44 of electrodes to apply a 1-20 ms burst of RF current at 200-350 V base-to-peak (i.e., 400-700 V peak-to-peak) and 50-500 kHz (e.g., 100 kHz) to the epidermis (and typically superficial dermis) of skin surface 42.

When apparatus 40 drives a sufficient amount of energy through the epidermis (and typically superficial dermis), during the first time period, these skin layers are ablated by the energy dissipating through them. Each individual electrode typically applies this current at a current of 1-20 mA. Typically, 2-12 electrodes (e.g., four electrodes) are simultaneously driven to drive the RF current into the skin, resulting in a correspondingly higher total instantaneous current (e.g., 4-80 mA). The remaining electrodes in array 44 typically serve as return electrodes, and due to their greater number, the return electrodes produce substantially lower current densities in the skin. This ablation creates micro-channels 50, i.e. physical pores in the epidermis (and typically superficial dermis). Micro-channels 50 are accurately reproducible as well as typically small and not visible to a naked eye. Depending on local skin conditions and the current protocol used, the micro-channels are typically 40-100 μm in diameter, and 50-400 μm (e.g., 30-200 μm) in depth.

When each micro-channel 50 has formed in response to current flow by the electrodes, it remains an empty pore until body fluid permeates it. Typically, a given micro-channel 50 is filled by natural body fluid within approximately 30 ms after formation of the micro-channel has occurred. Ablation of micro-channels 50 generally does not cause pain or sub-

stantial trauma to skin layers underlying the superficial dermis. Although any wound caused by ablation of the skin is minimal, a natural process of wound healing is induced by formation of micro-channels 50. Production of collagen, which occurs naturally as part of wound healing, leads to a smoother, elastic skin appearance.

Reference is made to FIG. 1C, which is a schematic illustration of array 44 positioned in contact with skin surface 42, without having been moved from the site where ablation was produced, in accordance with some applications of the present invention. As described hereinabove, energy source 46 drives electrodes 60 to apply current at different voltages during two time periods. FIG. 1C represents the second time period, in which energy source 46 applies energy to drive the electrodes to apply current at a lower voltage than was applied during the first time period. Although the current applied by the electrodes during the second time period can be AC or DC and can have a range of parameters that would induce heating, the current typically has a frequency of 50-500 kHz (e.g., 100 kHz), and may, for example, have the same frequency as that applied during the first time period.

In accordance with a protocol for the first and second time periods, ablation through a given electrode, or small group of electrodes (e.g., four electrodes) is performed during the first time period for that subset of one or more electrodes. Then, another subset of one or more electrodes ablates, during a first time period for that subset of electrodes. This process is repeated until typically substantially all of the electrodes have applied ablating energy to the skin. Subsequently, in the second time period, current is applied at a lower voltage through all of the electrodes, in order to induce uniform heating across the area of skin under array 44. The current driven by energy source 46 during the second time period is typically (but not necessarily) less than 100 mA, and is usually about 10-50 mA. The current driven through any one electrode during the second time period is typically 0.1-1 mA. For some applications, e.g., when array 44 has a smaller number of electrodes, or not all of the electrodes are applying current simultaneously, the current driven through any one electrode may be 1-10 mA.

In some applications, the second period of time is initiated on an electrode-by-electrode basis or a subset-by-subset basis, typically at least 10 ms from the termination of the first time period at any given electrode. For example, each electrode, or small subset of electrodes, may have its own first and second time periods, before another electrode or subset of electrodes has its first time period. For some applications, a first subset of one or more of the electrodes are applying energy in accordance with a first time period protocol, while another subset of one or more electrodes are applying energy in accordance with a second time period protocol.

Typically, in at least one operational mode of apparatus 40, the number n2 of electrodes applying non-ablating energy during any given second time period is higher than the number n1 of electrodes that apply ablating energy during any given first time period. For example, n2 is typically at least 3 or 10 times higher than n1.

The duration of current application during the second time period is typically 1-30 seconds, or 30-200 seconds. The energy applied during the second time period is non-ablating, but typically sufficient to heat body fluid 54 present within micro-channels 50 to a temperature suitable for inducing ongoing changes to collagen. In an experiment, an array 44 of 144 electrodes, 70 μ m in length, applied 100 kHz current to a volunteer during the first time period for 7 ms at 200 V base-to-peak, in order to ablate at least a portion of the epidermis, and produce micro-channels. During the second time

period, array 44 was maintained at the same place as during the first time period, and applied 100 kHz current for approximately 20 seconds, at 80 V base-to-peak. The volunteer reported no unpleasant sensation due to current application during either period. In other experiments described hereinbelow, similar first-time-period protocols were used, without a second time period, and produced measurable wrinkle reduction. In this first and second time period experiment, no measurements were made of wrinkle reduction.

Heating body fluid 54 within micro-channels 50 leads to the controlled heating of underlying collagen tissue, causing thermally-mediated collagen contraction. Thermally-mediated collagen contraction, or shrinkage, typically results in a tightening effect of the skin. Skin tightening and wrinkle reduction are the synergistic effect of the ablation and lower-temperature heating methods of these embodiments of the present invention.

Typically, the use of apparatus 40 results in skin rejuvenation and wrinkle reduction.

In experiments described hereinbelow, performed by the inventors using a version of apparatus 40 that only ablates and does not utilize heating during the second time period, ablation of micro-channels 50 was found to trigger a wound healing process in the skin, in which collagen formation is naturally induced.

The following examples are provided in order to illustrate the effects of embodiments of the present invention.

FIG. 2 is a graph representing the average changes in wrinkle depth in response to treatment by the method and apparatus for electrical skin rejuvenation, in accordance with some applications of the present invention. In this set of experiments, wrinkle depth on a subject's forehead was determined by silicone imprint analysis of the wrinkles examined. Skin surfaces containing wrinkles from eight subjects were subjected to two treatments with apparatus 40 separated by one month, and measurement were taken prior to the first treatment, and over the course of the next two months. Each treatment comprised applying RF energy through 200 μ m long electrodes in an array 44 of 144 electrodes, at a voltage of 330 V and a frequency of 100 kHz. The energy was applied to the skin surface in one burst of energy, for a duration of 9 ms. Subsequently, array 44 was removed from the skin and then replaced, within the abilities of the experimenter, on essentially the same location (but not the identical location), such that effectively the same area of skin was covered by the array, even though the electrodes were at an uncontrolled location with respect to the previously-generated micro-channels. Current was applied again, using the same protocol. Subsequently, array 44 was again removed and replaced, and current was applied a third time, again using the same protocol.

As shown in FIG. 2, there is a clear change over time in wrinkle depth in treated skin surfaces over eight weeks. All subjects responded to the treatment and demonstrated gradual improvement and a decrease in wrinkle depth during the course of the study. After two weeks, four weeks and eight weeks the average improvement was 11.06%, 18.25% and 25.3% respectively.

Table I is a table representing skin analysis of eight subjects following treatment by the method and apparatus described herein for electrical skin rejuvenation, in accordance with some applications of the present invention, using the protocol described hereinabove with reference to FIG. 2.

TABLE I

Group	Subject Number	Subject Age	Epidermis Cell Proliferation		Collagen Fiber Content	Elastin Fiber Content
			Treated	Non-treated		
A	1	35	23	19	no change	no change
A	2	40	14	16	no change	no change
A	3	41	31	19	no change	no change
A	4	42	12	30	no change	increase in fiber content
B	5	47	60	37	increase in fiber content	increase in fiber content
B	6	47	25	18	small increase in fiber content	increase in fiber content
B	7	50	20	13	increase in fiber content	no change
B	8	51	56	16	increase in fiber content	increase in fiber content

In this set of experiments, forearm skin biopsy samples were taken from treated and non-treated skin surfaces of eight subjects. The subjects were divided into two age groups. The younger age group (35-42 y) was designated group A, and the older age group (47-51 y) was designated group B. The skin samples were analyzed for collagen and elastin content, as determined by collagen and elastin staining; and epidermal cell proliferation, as determined by a specific marker for proliferating cells (Ki67). As shown in Table I, all subjects in group B showed increased collagen fiber content and increased skin cell proliferation in response to treatment by the method and apparatus for skin rejuvenation, in accordance with some applications of the present invention. Additionally, 75% of the subjects in group B, showed an increase in elastin fiber content. In contrast, the collagen fiber content of subjects in group A was not altered by the treatment. In addition, only 25% of the subjects in group A showed increased elastin content and 50% exhibited increased cell proliferation in response to treatment. Separate results (not shown) demonstrated that pain, erythema, and edema produced during the study were acceptable in each of the test subjects.

Trans Epidermal Water Loss (TEWL) was analyzed following treatment of skin surfaces of foreheads and forearms of subjects. The skin surfaces were treated with the method and apparatus for skin rejuvenation, in accordance with some applications of the present invention. Analysis of the results of the studies performed on the forearm site show that following the first treatment, TEWL value was significantly higher than the TEWL value measured prior to initiation of treatment (as measured with a VapoMeter (Delfin Technologies, Ltd.) ($p=0.012$) and according to the Wilcoxon signed-ranks test. TEWL values remained significantly elevated for 48 hours to one week following treatment. (Similar results were obtained for the forehead site.)

It will be appreciated by persons skilled in the art that the present invention is not limited to what has been particularly shown and described hereinabove. Rather, the scope of the present invention includes both combinations and subcombinations of the various features described hereinabove, as well as variations and modifications thereof that are not in the prior art, which would occur to persons skilled in the art upon reading the foregoing description.

The invention claimed is:

1. A method for reducing a wrinkle on a skin surface, comprising:

identifying a skin surface with a wrinkle;

positioning at respective sites on the skin surface an array of electrodes communicatively coupled to an energy source; and

while the electrodes are positioned at the respective sites:

during a first time period, applying energy from the energy source to drive the electrodes to apply a radio frequency (RF) current at a first voltage sufficient to ablate micro-channels in the epidermal layer of the skin and, at least partially, ablate collagenous dermal tissue, the micro-channels accessing the ablated collagenous dermal tissue; and

during a second time period, applying energy from the energy source to drive the electrodes to apply a current at a second voltage lower than the first voltage;

wherein applying energy during the second time period comprises initiating application of the energy:

at least 10 ms after the first time period application of energy; and

subsequent to filling of the micro-channels with body fluid.

2. The method according to claim 1, wherein applying energy during the first time period comprises applying the energy for 1-20 ms.

3. The method according to claim 1, wherein applying energy during the second time period comprises applying the energy for at least 1 second.

4. The method according to claim 1, wherein applying energy during the second time period comprises applying only non-ablating energy during the second time period.

5. The method according to claim 1, wherein applying energy during the first time period comprises setting a voltage of the energy applied during the first time period to be 150-350 V base-to-peak.

6. The method according to claim 1, wherein applying energy during the second time period comprises setting a voltage of the energy applied during the second time period to be 10-200 V base-to-peak.

7. The method according to claim 1, wherein applying energy during the second time period comprises setting a voltage of the energy applied during the second time period to be 10-100 V base-to-peak.

8. The method according to claim 1, wherein applying energy during the first time period comprises setting a frequency of the energy applied during the first time period to be 50-500 kHz.

9. The method according to claim 1, wherein applying energy during the second time period comprises setting a frequency of the energy applied during the second time period to be 50-500 kHz.

10. A method for reducing a wrinkle on a skin surface, comprising:

identifying a skin surface with a wrinkle;

positioning at respective sites on the skin surface an array of electrodes communicatively coupled to an energy source; and

while the electrodes are positioned at the respective sites:

during a first time period, applying energy from the energy source to drive the electrodes to apply a radio frequency (RF) current at a first voltage for 1-20 ms, the first voltage sufficient to ablate micro-channels in the epidermal layer of the skin and, at least partially, ablate collagenous dermal tissue, the micro-channels accessing the ablated collagenous dermal tissue; and

13

during a second time period, applying energy from the energy source to drive the electrodes to apply a current at a second voltage lower than the first voltage for at least 1 second;
wherein applying energy during the second time period 5 comprises initiating application of the energy:
at least 10-99 ms after the first time period application of energy; and
subsequent to filling of the micro-channels with body fluid.

10

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14